TOTAL OPTICAL DEPTH ANALYSIS FOR NO_2, O_3 AND AEROSOLS BY A MULTI-FILTER SHADOWBAND RADIOMETER

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ABSTRACT

The main focus of this research is the retrieval of tropospheric aerosol information using a Multi-filter Rotating Shawdowband Radiometer, Model MFR-7, placed on the roof of the Science Building at Medgar Evers College. This instrument makes precise measurements of atmospheric extinction of the direct solar beam simultaneously at six wavelengths (415, 500,615, 670, 840 and 940 nm) at one minute intervals throughout the day. We are interested in measuring the changes in the optical depth of ambient aerosols, mass, effective particle size, aerosol size distribution, and chemical composition of ambient particulate matter the Greater New York City Area. Results will be compared with data obtained by A. Lacis, B. Carlson and B. Cairns at the NASA Goddard Institute for Space Studies.

INTRODUCTION

Interest in climate/human health relationships has increased during the late 1980s and 1990s, partly because of the availability of more complete databases and because of a human-induced global warming, which is predicted to increase the mean global temperature by 2-5 degrees Celsius over the next century. The measurements of the optical depth indirectly measures the concentration various greenhouse gases such as water vapor, aerosols, nitrogen dioxide and ozone. Subsequently, aerosol concentrations change over time; this is due to precipitation, wind speed and anthropogenic sources. This research will examine the effects of man-made pollution over a period of time over the Greater New York Region.

THE MFRSR SPECTROMETER

The multi-filter rotating shadow band radiometer (MFRSR) is a ground based instrument that uses independent interference-filter-photodiode detectors and the computer controlled automated rotating shadow-band technique to make spectrally resolved measurements at seven wavelengths of direct-normal, total-horizontal, and diffused-horizontal irradiances. The three irradiance components are measured with the same detector for a given wavelength. The measurement sequence starts with a measurement made while the band is at nadir; this is the total horizontal irradiance. The band is then rotated so that the three measurements are made in sequence. The middle one blocks the sun, to give the diffuse horizontal irradiance, and the other two block strips of the sky 9^{o} to either side.

These side measurements allow for a first order correction for the excess sky blocked by the band when the sun-blocking measurement is made. Finally the diffused component is subtracted from the total horizontal component to give the direct horizontal component; the direct beam flux.

Direct Normal = Global - Diffused

The entire measurement sequence is completed for all wavelengths simultaneously in less than ten seconds and measurement sequences are performed every minute.

One can use the direct-normal component observations for Langley analysis to obtain depths and to provide an ongoing calibration against the solar constant by extrapolation to zero air mass. The long-term stability of all three measured components can be tied to the solar constant by an analysis of the routinely collected data. The MFRSR provides atmospheric (column) extinction of the direct solar beam simultaneously at six wavelengths (nominally: 415, 500,615, 670, 840 and 940 nm) at one minute intervals throughout the day. The choice of wavelength allows for the calculation of the optical depths for water vapor, aerosols, nitrogen dioxide and ozone.

Wavelength (nm)	Trace Species
415	aerosols
500	aerosols, ozone
610	aerosols, ozone
665	aerosols, ozone
862	aerosols
940	water vapor

The results of Multi-spectral Atmospheric Column Extinction (MACE) analysis then yield detailed time series information on the variations of the column amounts of atmospheric NO_2 and Ozone, and aerosol size distribution.

The MFRSR records the changes in atmospheric column extinction. I_{in}, measures atmospheric extinction using the six spectral intensities and is given by

$$I_{in} = C_n I^o{}_n \exp\left(-T_{in}/\bigcirc_i\right),$$

where $\bigcirc_i$ is the solar zenith angle, T_{in} is the atmospheric column extinction optical depth, $I^o{}_n$ are the total optical atmosphere (TOA) solar radiation intensities at MFRSR wavelengths, and C_n are the respective calibration coefficients. From the above equation, we can solve for the optical depth

$$T_{in} = \bigcirc_i \log\left(-I^o{}_n/I_{in}\right) + \bigcirc_i \log(C_n)$$

ELECTROMAGNETIC RADIATION

All the information that we obtain about the world around us (universe) comes to us by electromagnetic radiation. There is a Particle-Wave duality of light. Sometimes light behaves as a wave (e.g. interference, diffraction) and sometimes it behaves like a particle, called a photon (e.g. photoelectric effect, Compton effect). The relationship between velocity, frequency and wavelength (wave) of electromagnetic radiation is given by

$$c = \blacksquare \quad \bullet$$

The energy of a photon (particle) is given by

$$E = h■$$

where $h = 6.6 \times 10^{-34}$ J/s is Planck's constant. This also indicates that energy is quantized.

Electromagnetic radiation interacts with matter; physical properties that can be observed and measured are transmission, absorption, reflection, refraction, polarization and scattering. The scattering property is of special interest. There are two forms of scattering which are applicable to the principles of remote sensing: Rayleigh Scattering and Mie Scattering.

Rayleigh Scattering: The molecules are many times smaller than the electromagnetic radiation wavelength. The amount of scattering, I, is given by

$$I_{scat}$$ ✪

The advantages of Rayleigh scattering are that it is strongly wavelength dependent and often only in the direction of energy propagation; and it does not depend on atmospheric conditions.

MIE Scattering: This occurs in conditions were the electromagnetic radiation wavelength and the particle size are the same. The larger particles in the atmosphere such as dust and water vapor are responsible for Mei Scattering. The long wavelengths in the red region are effected by Mei scattering.

REMOTE SENSING

Remote Sensing describes any method by which data can be measured over a large area without making any physical connection with the object being measured. There are two classifications of Remote Sensing Systems: Active or Passive; and Imaging or Nonimaging.
Active Remote Sensing: An active system transmits an electromagnetic radiation signal and receives the back scattered reflected signal (e.g., radar).
Passive Remote Sensing: A passive system only receives electromagnetic radiation (e.g. cameras, thermal scanners, multispectra scanners - Landsat Satellite).
Most remotely sensed data are collected using passive remote sensing systems. Nonimaging are quantitative/digital and can be presented as line plots are serial data. Imaging formats are spatial and utilize shades, patterns or colors to visually represent qualitative or quantitative data.

PRELIMINARY RESULTS

The data collected thus far are uncalibrated, in units of mW and are then converted to W/m^2-nm. The collected data (spectral lines) has been separated using Excel 4.0. We have collected 20 days (June, July) of data to be used in a time based MACE At this time, the MFRSR is not calibrated; we are obtaining milliwatt values which need to be corrected to watts/meter^2-nanometer (mW/m^2-nm). The collected data (spectra lines) has been separated using Excel 4.0. We have collected 20 days of data to be used in the time-based MACE analysis. The graphs show a one day sample of data at six different wavelengths measured simultaneously. In addition, a sequence of graphs show global, diffuse and direct normal components.

FUTURE WORK

1. Make analytical comparison of our preliminary data with data obtain by the radiometer at the Goddard Institute for Space Studies.
2. Calibration of MFRSR with mercury arc lamp spectral lines.

3. Analyze calibrated or uncalibrated data by the Langley Analysis.
4. Sweeping off data from MFRSR to the Dell PC to the Sun Solaris workstation using the rsrsplit file.
5. Compilation of Hierarchy Data Format (HDF) read software for satellite data formats in C++ on to Sun Solaris workstation.
6. Provide access to a range of satellite data on Sun workstations for possible use in the project. We will compare MFRSR results to EPA, TOMS data from the NIMBUS-7 satellite spectroscopic profiles for our longitude and latitude.
7. Use IDL 5.2 software to compose global model correlations from all sources.

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